Self-Assembly of Magnetic Atoms on Stanene

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Introduction

Magnetic topological insultors

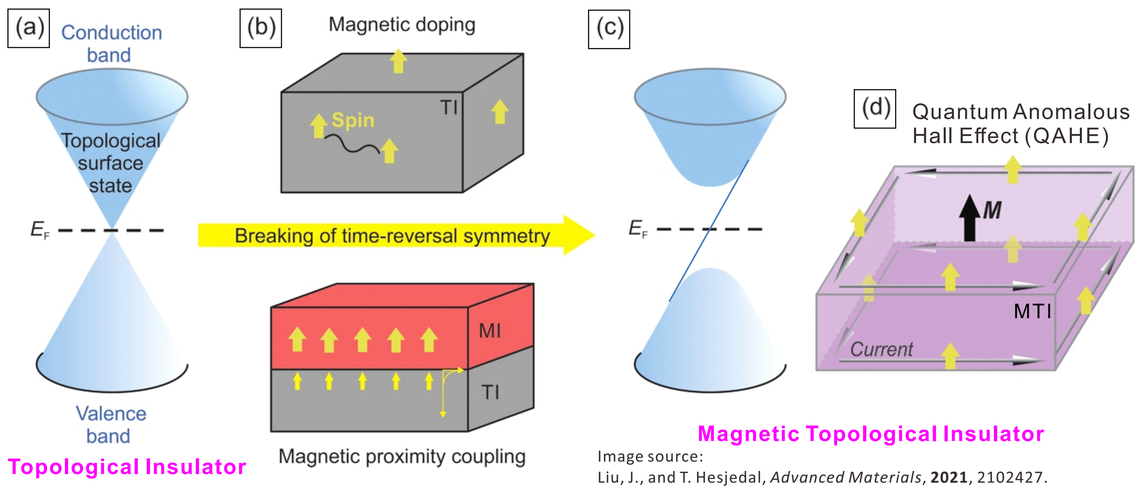
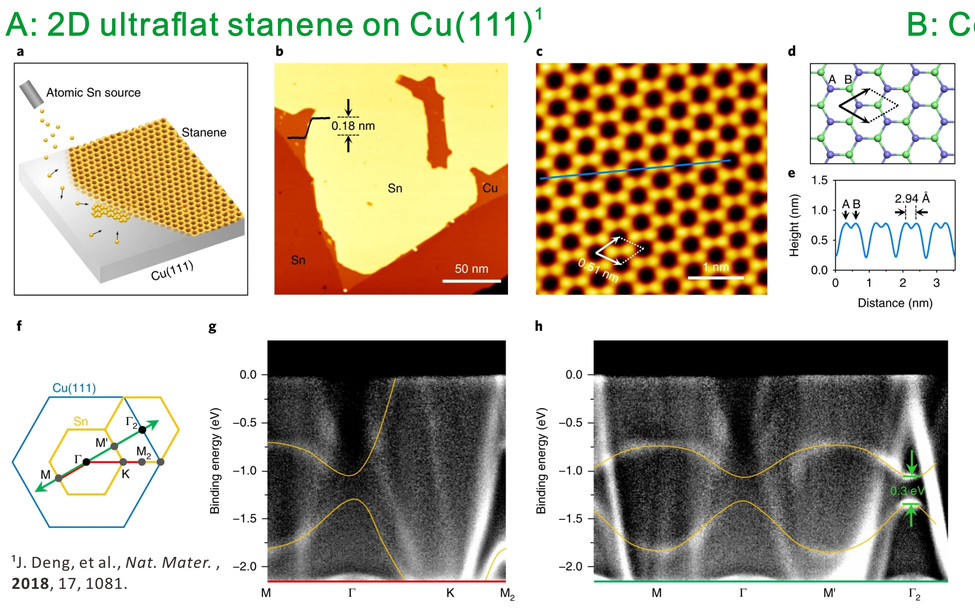


Image source:
Liu, J., and T. Hesjedal, *Advanced Materials*, **2021**, 2102427.

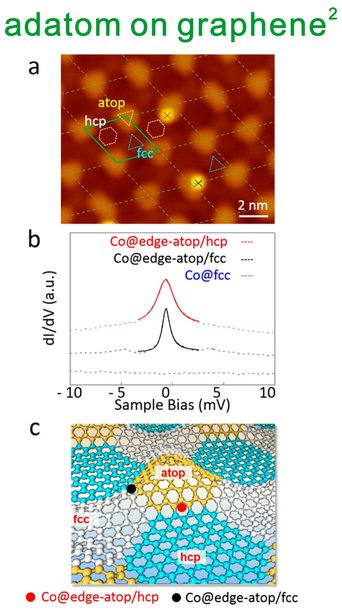
Literature review

A: 2D ultraflat stanene on Cu(111)[1]



[1] J. Deng, et al., *Nat. Mater.*, **2018**, 17, 1081.

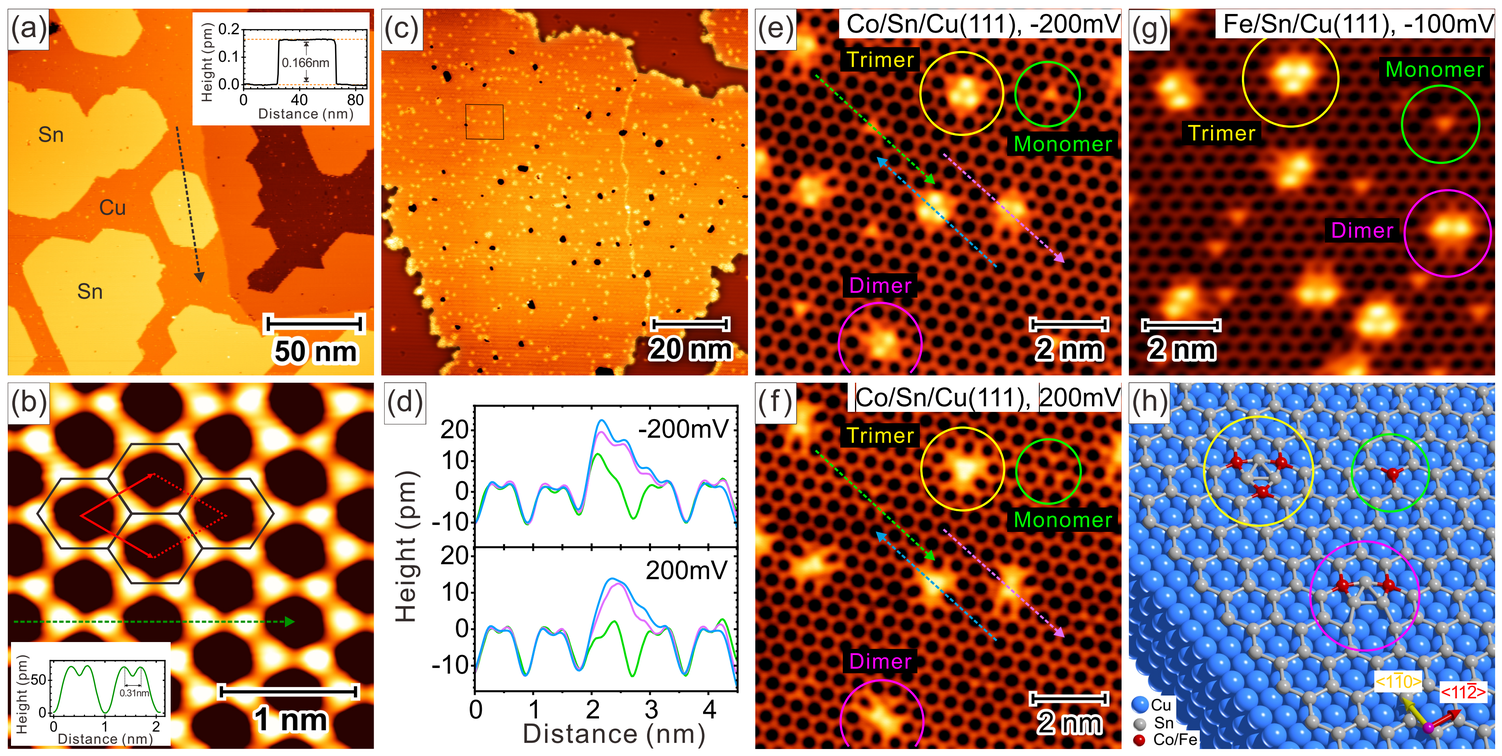
B: Co adatom on graphene[2]



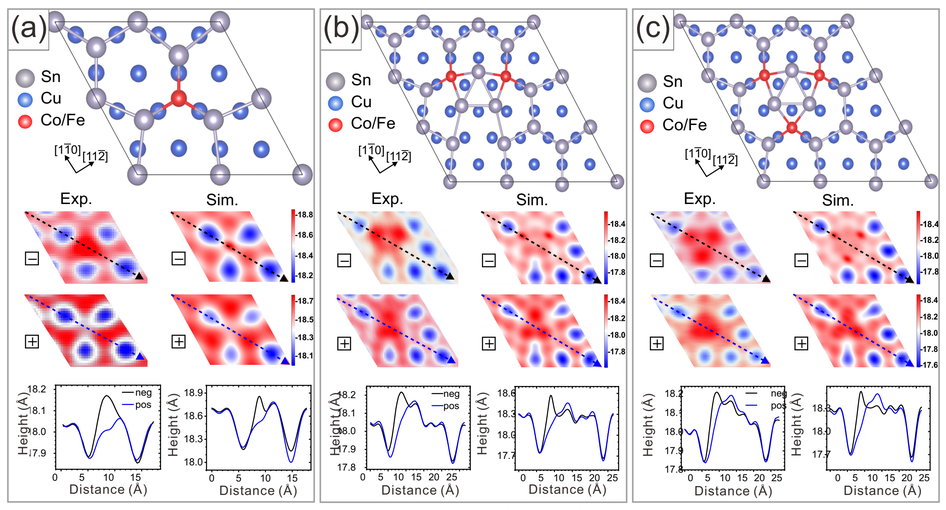
[2] J. Ren, et al., *Nano Lett.*, **2014**, 14, 4011.

Results

Topography

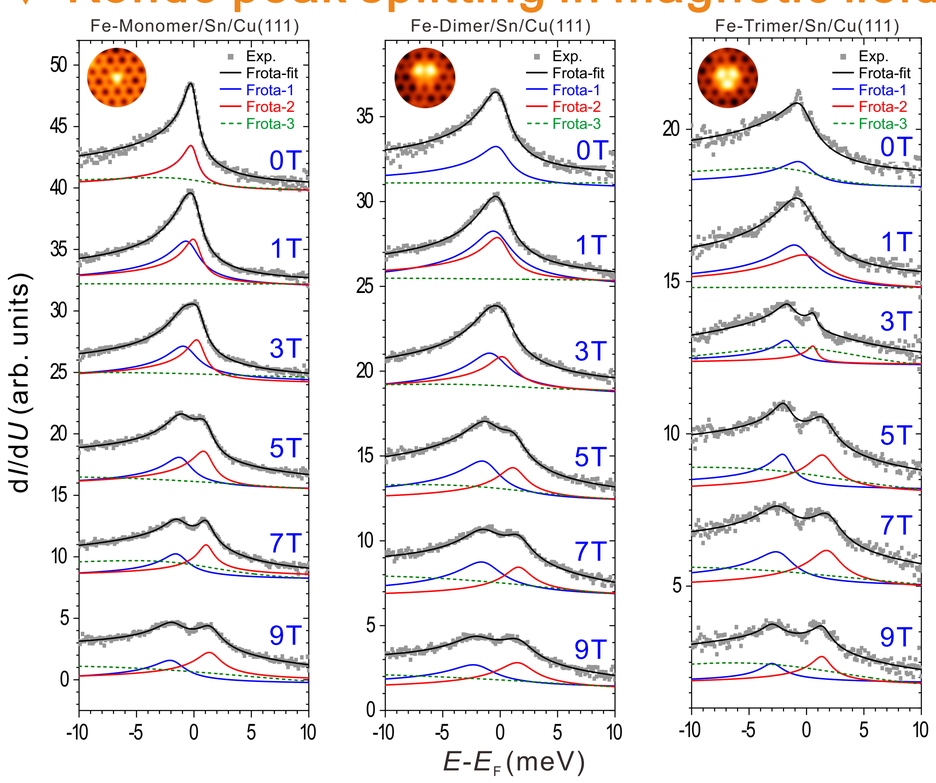


Atomic structure

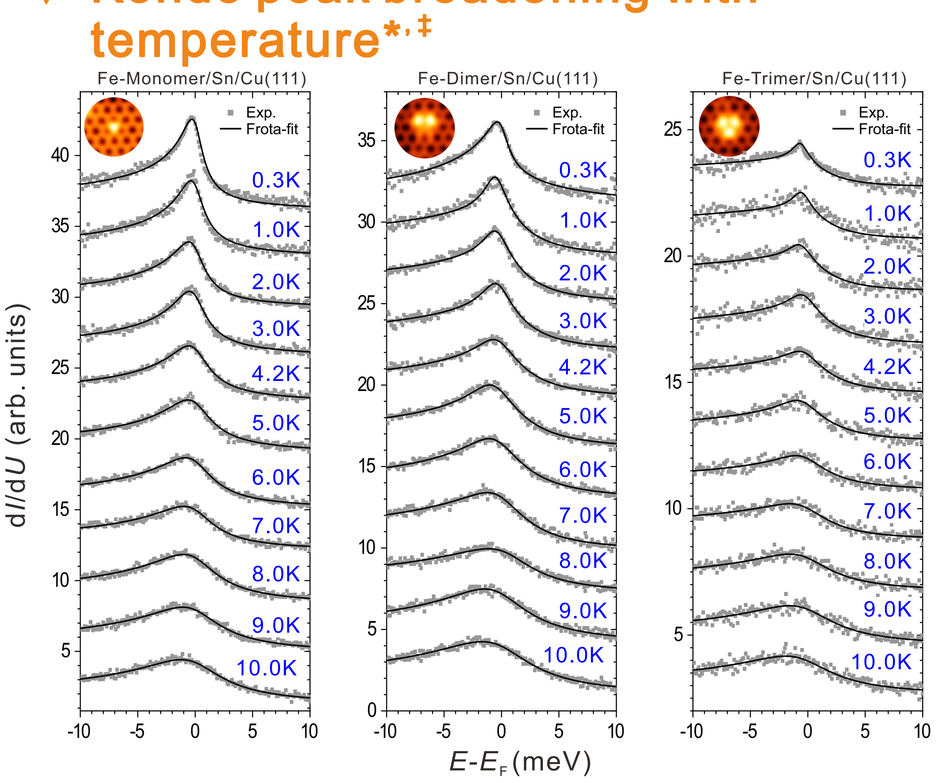


- Magnetically (Fe/Co atoms) doped two-dimensional monolayer stanene was grown on Cu(111) substrate by using molecular beam epitaxy at 80 Kelvin.
- Magnetic atoms (Fe/Co) have been doped subsequently at same temperature.
- A low-temp. (0.3K) STM/STS with 9T B-field has been used for investigation.
- Atomic structures have been deduced based on STM images and DFT.
- A non-zero total spin has confirmed by observing the Kondo effect.

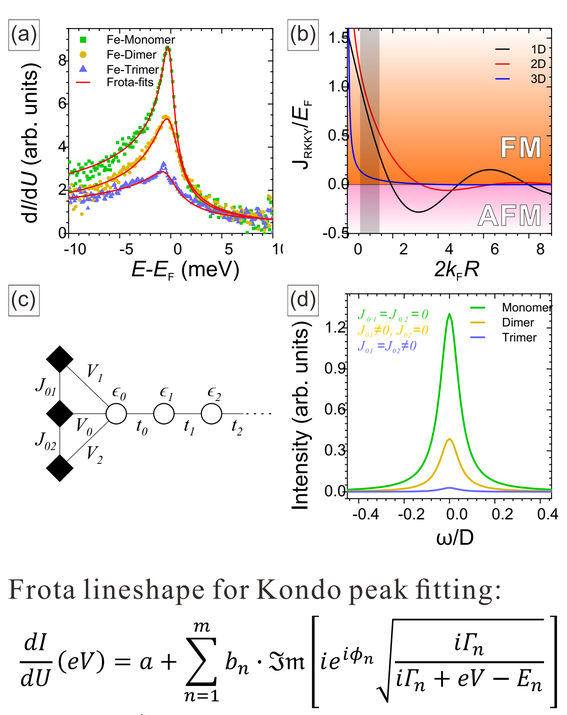
Kondo peak splitting in magnetic field†



Kondo peak broadening with temperature*,‡



Theoretical Results



Frota lineshape for Kondo peak fitting:

$$\frac{dI}{dU}(eV) = a + \sum_{n=1}^{m} b_n \cdot \Im\mathfrak{m}\left[ie^{i\phi_n}\sqrt{\frac{i\Gamma_n}{i\Gamma_n + eV - E_n}}\right]$$

*m=1; †m=3;

$$\Gamma_{HWHM} = 2.542 \times \Gamma$$
$$Energy\ shift = \tfrac{1}{2}|E_1 - E_2|$$

‡Fermi-liquid model:

$$\Gamma_{HWHM}(T) = 3.7\sqrt{(\alpha k_B T)^2 + (k_B T_K)^2}$$

$\alpha = \pi$ (theoretical value)
T_K = Kondo temperature
T = Sample temperature

#Effective spin Hamiltonian:

$$\hat{\mathcal{H}}_{spin} = g\mu_B \hat{\vec{S}}_{eff} \cdot \vec{B} + D\hat{S}^2_{eff_z} + E(\hat{S}^2_{eff_x} - \hat{S}^2_{eff_y})$$

Summary

- Co and Fe impurities have self-assembled on monolayer stanene/Cu(111) in the form of monomer, dimer, and trimer.
- Kondo resonances at the Fermi level have been observed from the screening of the spins of Fe impurities as a hallmark of successful magnetization of stanene, however, the magnetic moments of the Co atoms are too small to effectively screened by itinerant electrons.
- Single Kondo peaks have split into two in external magnetic field and width of the peaks has broadened with temperature.
- The total effective spins of Fe atoms have found to be 3/2 by fitting the Kondo splitting with theoretical effective spin Hamiltonian#.
- Magnetic moment, amplitude of Kondo resonance, and Kondo temperature progressively decreased from monomer to dimer and trimer due to the interactions among magnetic atoms.

System	Magnetic Moment (μ_B)			Kondo Temperature (K)		
	Monomer	Dimer	Trimer	Monomer	Dimer	Trimer
Co/Sn/Cu(111)	0.60	0.56	0.29	-	-	-
Fe/Sn/Cu(111)	2.38	2.26	2.23	7.70	7.10	5.88